A HYDROGEOLOGICAL APPROACH OF THE OLD DRAVA RIVERBEDS' REHABILITATION

Dominika Pollermann*, Angéla Anda, Imre Müller

University of Pannonia, Georgikon Faculty, Keszthely, Hungary

*pollermann.dominika@gmail.com

Abstract

In the past decades the water management of the Ormánság used to be based on the drainage of surface waters instead of retaining them in the catchment area. However, the present aim of the new water regulation concept of Ormánság is the rehabilitation of the water management by transforming the straightened streams and drainage canals into the old, meandering, natural beds and in the meantime by increasing the surface water levels. These bed pathways could be completely new or they might remain in the already existing old Drava river beds.

The aim of our research consists of a hydrogeological approach of existing old riverbeds by soil analysis and by geophysical soundings, to determine the thickness and the hydraulic permeability of the sediments. With the help of this information we can conclude whether in the three pilot research sites the thickness and permeability of the river bed sediments would allow the renewal of permanent surface flow systems if artificial alimentary streams will feed them.

Key-words: Drava, Ormánság, water management, hydrogeology, geophysics.

Összefoglalás

Az Ormánság, bár mind néprajzi, mind pedig természeti szempontból jelentős értéket képvisel, jelenleg hazánk egyik legelmaradottabb térsége. Míg e vidéket egykor a Dráva áradásai éltették, a zöldellő legelők, az erdők, a folyó és holtágai jólétet biztosítottak, addig ma a térségnek komoly kihívásokkal kell szembenéznie. Az elmúlt évtizedekben ugyanis az Ormánság vízfolyásainak és belvízcsatornáinak medre beágyazódott, vízszintjük lesüllyedt, mely a táj kiszáradásához, szerkezetének átalakulásához vezetett.

Megszületett azonban az Ormánság vízrendezésének koncepciója, mely szerint a táj kisvízfolyásai és belvízcsatornái bevágódott, kiegyenesített medreikből régi vagy teljesen új, kanyargós medrekbe kerülnének, vízszintjüket megemelnék.

Kutatásunk célkitűzése a régi folyómedrek hidrogeológiai vizsgálata volt. Talajfizikai vizsgálatokat és geoelektromos szondázásokat végeztünk a medrekben lerakott üledék vastagságának, permeabilitásának és térbeli elhelyezkedésének meghatározása érdekében. Ezen adatok ismeretében ugyanis következtethetünk arra, hogy ha az egykori folyómedrekre vízfolyásokat engednek, a régi medrek üledékeinek vastagsága és permeabilitása elegendő lesz-e ahhoz, hogy tartós vízborítás alakulhasson ki.

Introduction

Nowadays the Ormánság, situated in the southern part of Baranya County, is one of the most disadvantaged areas in Hungary (http://baranyakonf2013.pte.hu/en/about-us/old-drava-program/). However the ethnographical and natural values of this region are of paramount importance. The floodplain of the Drava, the oxbow lakes, wetlands and marshes provide habitats for a valuable wildlife. For example there are 56 protected plant species and 49 endangered plant communities in the Ormánság, and ornithological biodiversity the area of the Drava is not only of national but also of international importance (Rményi and Tóth, 2009). Along the river an especially diverse range of habitats can be found, and there are numerous geomorphological phenomena that cannot be detected in the majority of regulated flowing waters (Závoczky, 2005).

The wealth of the area was provided by the floods of the Drava but in the recent times many adverse change occurred (http://www.osdrava.hu/download/tajgazdalkodasi.pdf). In the last centuries the meandering streams of the Ormánság were straightened and drainage canals were constructed. Later the straightened beds became deeper and deeper. The streams and drainage canals started to draw off the water from the area and caused the dehydration of the region (Molnár, 2012).

Currently the water management of the Ormánság is based on the draining of water. In rainy periods precipitation cannot infiltrate and leave the area as surface runoff. In dry periods the catchment area - unlike the small permanent reservoirs - cannot retain the water (Molnár, 2012).

The continuous decrease of the water resources of the land threats the valuable wildlife of the Ormánság by changing the living conditions. The decreasing water and forest surface diminution induce also a reduction in the amount of evaporation, which produces the breakdown of the microregional water circle (Molnár, 2012). In the same time the land use has been changed. Decades ago the land was used as orchard, pasture, meadow, forest or fishpond, which were replaced by industrial agriculture (http://www.osdrava.hu/download/tajgazdalkodasi.pdf). The traditional way of making a living for the inhabitants, such as fishing, fruit growing and the grazing animal husbandry disappeared. As a result, besides the degradation of the natural ecosystem the social and economic impoverishment started as well (http://baranyakonf2013.pte.hu/en/about-us/old-drava-program/). Nowadays the area is characterised by poor living conditions and low level of education (Jelenszkyné Fábián, 2009). In addition the rate of the job-seekers in the Sellye microregion is four times higher, than the Hungarian average (Tésits, 2007).

Phrase rehabilitation means applied measures for re-establishing an area, rivers are included, close to near-natural condition (Pickett et al. 2001). These authors called the attention that although these measures address ecological issues, other impacts for society may arise as well. Due to complexity of the issue, separate evaluation is essential (Gardiner 1992). Habersack et al. (2008) published that out of 139 river systems of US, Europe and the former Soviet Union, 77% of them has to be classified as negatively impacted by human activity.

There are projects such as Old-Drava Program and Old-Drava ORMÁNSÁG Program in order to develop the Ormánság, which define the modification of water management of the region as an important factor of development. The aim of the new water regulation concept of the Ormánság is to build up a surface flow network and land structure reorganisation, which will be able to retain the water in the area. The reorganisation of the water management would concern all streams and drainage canals in the area. They will be directed back into their former meandering riverbeds from their current, straightened beds and their water level will be artificially raised. This intervention will help to store the water in the area, increase water resources and reconstruct the microregional water circle and landscape structure (Molnár, 2012).

Korcsina Canal, which is one of the most important drainage canals in the Ormánság, is in the centre of our research. A detailed study already exists, which plans the reconstruction of the Korcsina Canal, including a concrete proposal about the new, meandering and natural fall line following the riverbeds instead of the present pathway. Before we start this project it is important to explore the permeability and the thickness of the sediment fillings at the bottom of these old river beds to estimate their storage capacity by artificial recharge. This is the goal of the present research.

Materials and methods

The field measurements were carried out in October 2012 and July 2013 in the area of Drávafok – Markóc – Drávakeresztúr, which belongs to the floodplain of the Drava River and the catchment area of the Korcsina Canal. In this region three pilot study areas (A, B and C study areas) were appointed crossing old riverbeds. The realization of the water regulation concept of Korcsina means an artificial recharge planned to be led through these study areas.

During the research six manual drillings were carried out, two on every study area, down to 250-300 cm with Eijkelkamp drilling equipment. From every drilling 3-5 soil samples were collected according to the change of the soil type. The mechanical composition of the samples was determined using the pipette method (Buzás, 1993). During the process at first sodium pyrophosphate was given to the dried soil samples. Then the suspensions were shaken in a soil shaker for 6-10 hours in order to disintegrate the probe to smaller particles. Next the suspensions were poured into a measuring cylinder through a sieve with an 0.25 mm hole diameter. The part of the sample which could not flow through the sieve was the biggest fraction. To determine the smaller fractions the measuring cylinder was put aside to settle. After suspension fractions were pipetted at specified time intervals, from the specified depths, they were put in designated weights, in numbered beakers. The samples were dried in a drying cabinet at 105°C to constant weight. In the next step the weight of the samples was measured after drying. With the help of the Stokes equation the rate of the different fractions and the mechanical composition of the soil sample can be defined. The soil type was determined by the clay and silt content (less than 0.02 mm particle diameter) (Buzás, 1993).

Beside the soil measurements geophysical vertical electrical soundings (VES) were carried out. Geoelectrical methods are based on the ability of rocks to conduct electric current. Saturated rocks have lower resistivity than unsaturated and dry rocks (Müller et al., 2008). The presence of clays reduces the resistivity. The resistivity of rocks can be studied by measuring the electrical potential distribution produced at the Earth's surface by an electric current that is passed through the soil via two electrodes (A and B). The potential difference resulting is measured between a second pair of electrodes (M and N). The current and potential measurements may be used to calculate specific resistivity (Ωm). The well-known Wenner array was used to explore the very shallow depth, down to 4-5 m fast and accurately. The four electrodes A, M, N, and B are placed at the surface of the ground along a straight line so that the distance "a" between all these electrodes will be the same. In electric sounding the electrode spacing "a" is increased at successive logarithmic intervals, and the value of the appropriate apparent resistivity is plotted as function of the electrode spacing on logarithmic coordinate. The successive apparent resistivity values give a sounding curve. Numerical interpretation of the Wenner sounding curves, to obtain trough resistivity and layer thickness, is not yet done because sharp layer boundaries does not exist in these sediments (Müller et al., 2008; http://www.epa.gov/esd/cmb/GeophysicsWebsite/pages/reference/ methods/Surface_ Geophysical_Methods/Electrical_Methods/Resistivity_Methods.htm).

In the present paper only qualitative interpretation of apparent resistivity data is used.

With the Wenner array five measuring points built up our sounding curves at every sounding location. The spacing between A-M-N-B electrodes which are marked with "a", are: 0.25 m, 0.5 m, 1 m, 2 m and 4 m. The depth of the sounding is estimated with the favourite rule-of-thumb, the electrode spacing is equal to the depth of probing (Müller et al., 2008).

At the "A" pilot- study area 13, at "B" area 8 and at "C" area 12 geophysical soundings were carried out crossing the old riverbeds. The mechanical composition of the soil samples from the drillings and the apparent specific resistivity measured on the same location were compared. In the next step the existing visible correlations between resistivity values and the characteristic of the different soil types were estimated. This relation was used to draw the soil profiles of the pilot-study areas transforming the resistivity values to different soil types.

Results and Discussion

The results of the soil analysis were summarized in Table 1. The upper layer of the first drilling was silt but deeper sand was also found. In the case of the second drilling the upper layers were clay, silt and clay, following by silt and sand in the deeper layers. The top layer of the third segment was silt but deeper clay was the specific sediment. The soil types of the fourth and fifth drillings were similar to the first one; the upper layer was silt, but in deeper layers sand were found. In the case of the sixth segment only sand was defined.

The following diagrams present the results of the geophysical soundings in log-log scale, measured at the drilling points. On the X axis the "a" values were represented, which means the distance between the electrodes and corresponds approximately to the depth penetration of the sounding. On the Y axis the apparent resistivity can be seen. Also the specific soil types of the sample were represented on the graphs. In the case of the first drilling the resistivity is about 37-51 Ωm down to the depth of about 1 meter. The characteristic soil type of this layer was silt. Deeper sand layer was detected. The changing of the soil type was presented with the increase of the resistivity (Fig. 1).

Table 1 Mechanical compositions and soil types

Segment	Sample number	Clay %	Silt %	Sand %	< 0.002 mm particle diameter (%)	Soil type
Drilling 1	1/1	19.0496	59.8905	21.0600	49.6619	silt
	1/2	21.5352	58.7098	19.7550	47.4064	silt
	1/3	13.6442	51.2468	35.1091	41.3578	silt
	1/4	4.9299	15.6053	79.4648	12.0899	sand
	1/5	2.4372	11.4963	86.0665	9.2516	sand
Drilling 2	2/1	27.1802	59.9584	12.8614	66.2139	clay silt
	2/2	41.0870	56.3289	2.5841	80.0533	clay
	2/3	36.9387	51.7346	11.3267	74.9634	clay
	2/4	8.5219	74.7636	16.7144	30.2374	silt
	2/5	6.4720	74.8624	18.6656	18.1380	sand
Drilling 3	3/1	27.2571	42.3131	30.4298	57.0972	silt
	3/2	16.8456	81.4284	1.7260	83.7748	clay
	3/3	22.3113	68.8513	8.8374	75.1888	clay
Drilling 4	4/1	9.6633	35.1996	55.1371	30.1572	silt
	4/2	13.4560	29.8111	56.7329	29.4424	sandy silt
	4/3	15.7243	22.9629	61.3128	27.8697	sandy silt
	4/4	2.8703	6.4462	90.6834	6.0614	sand
Drilling 5	5/1	11.9808	59.1258	28.8934	40.8060	silt
	5/2	10.2950	58.7754	30.9296	35.2231	silt
	5/3	8.7461	51.6393	39.6146	27.7847	sandy silt
	5/4	7.0208	39.5586	53.4206	24.7907	sand
Drilling 6	6/1	6.4355	41.1773	52.3872	21.6935	sand
	6/2	3.0026	14.5635	82.4339	7.4664	sand
	6/3	3.8938	22.6390	73.4672	11.2310	sand

The geophysical sounding at the second drilling gave lower specific resistivity values as in the case of the first one. Down to the depth of 1 meter the values were situated between 13 and 32 Ωm and the soil type is clay and silty clay. The deeper layers were silt and sand layers. However, the specific resistivity values were not so high, which ought to characterise sand. This can only occur because of the presence of some conductive lenses (Fig. 2).

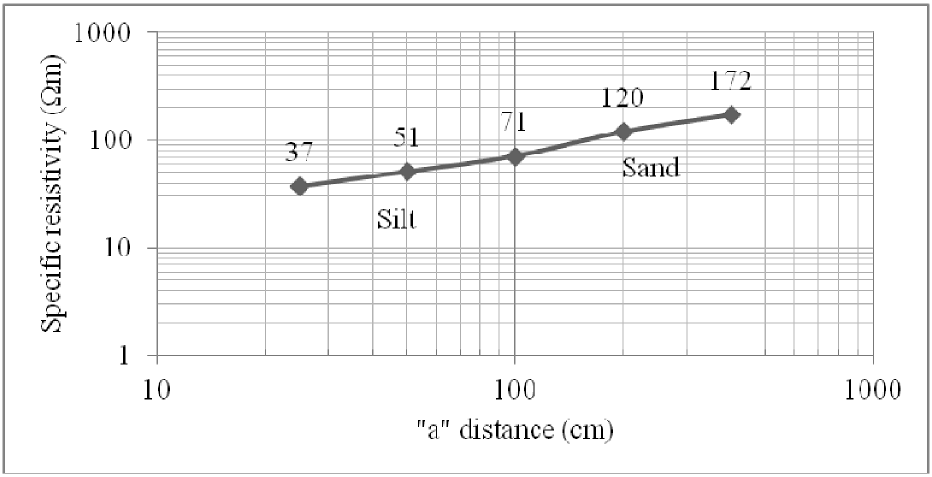

Figure 1. Results of the geophysical sounding at the 1st drilling

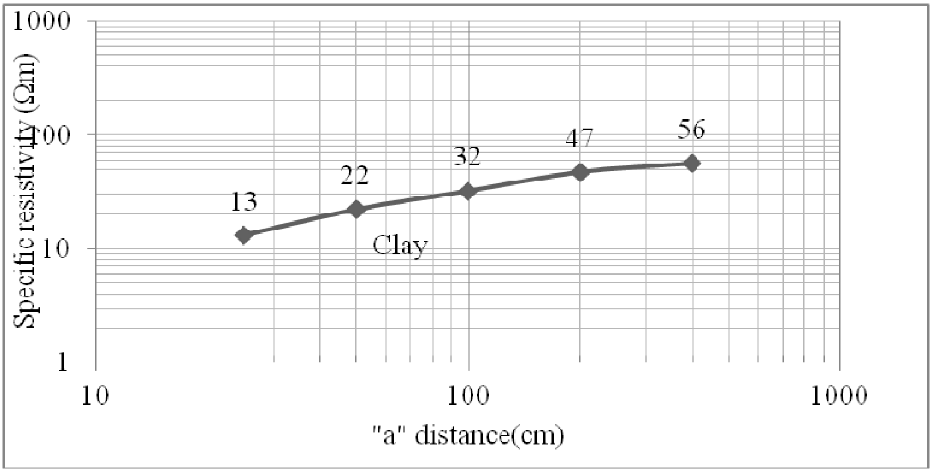

Figure 2. Results of the geophysical sounding at the 2nd drilling

The topsoil of the third segment was silt but the deeper clay was also present. With the change of the soil type the resistivity values varied simultaneously. The values in the case of the topsoil were situated between 63 and 44 Ωm but deeper, in the clay layer lower resistivity values were measured in the range of 20 Ωm (Fig. 3).

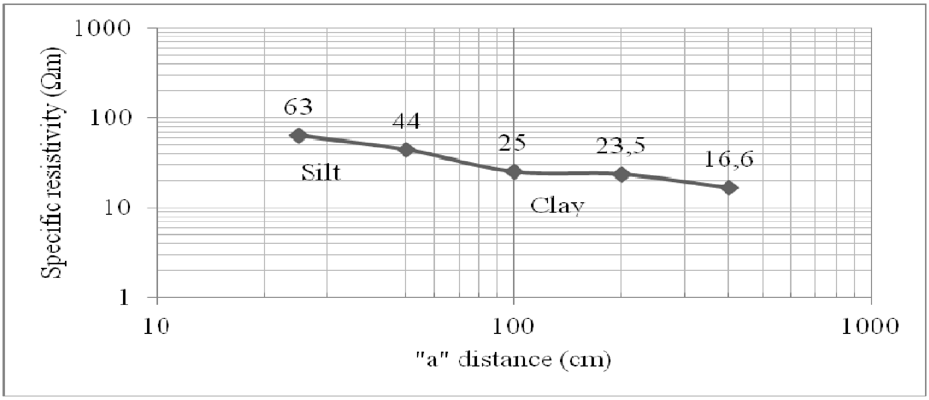

Figure 3. Results of the geophysical sounding at the 3rd drilling

The topsoil of the fourth segment was silt with the specific resistivity of 88 Ωm. Below a thin silt layer, sand and sandy silt were found. The resistivity values are about 110 and 203 Ωm in these layers (Fig. 4).

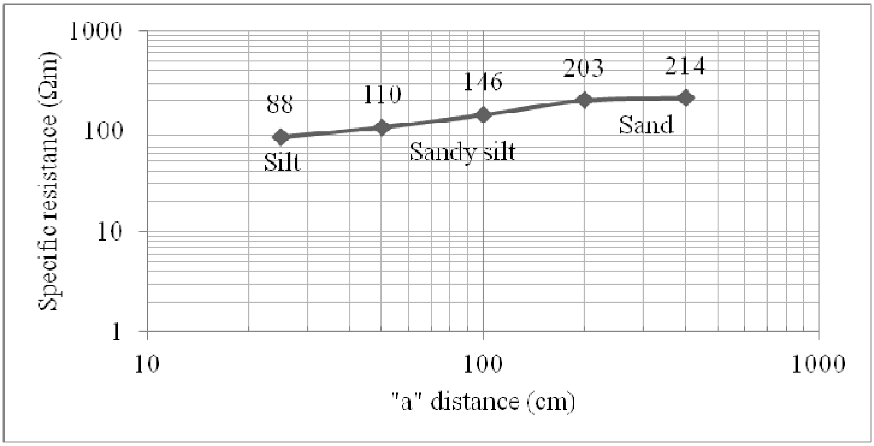

Figure 4. Results of the geophysical sounding at the 4th drilling

The upper layer of the next segment was silt and the resistivity values were 37 and 39 Ωm. Deeper, at 150 cm sandy silt and sand can be found. The resistivity values were similar to the second segment, probably due to the presence of the soil lenses (Fig. 5).

The first measured resistivity value at the sixth profile was 75 Ωm, indicating a thin silt layer but in the lower layers the results of the soil analysis were sand with higher resistivity between 117 and 326 Ωm (Fig. 6).

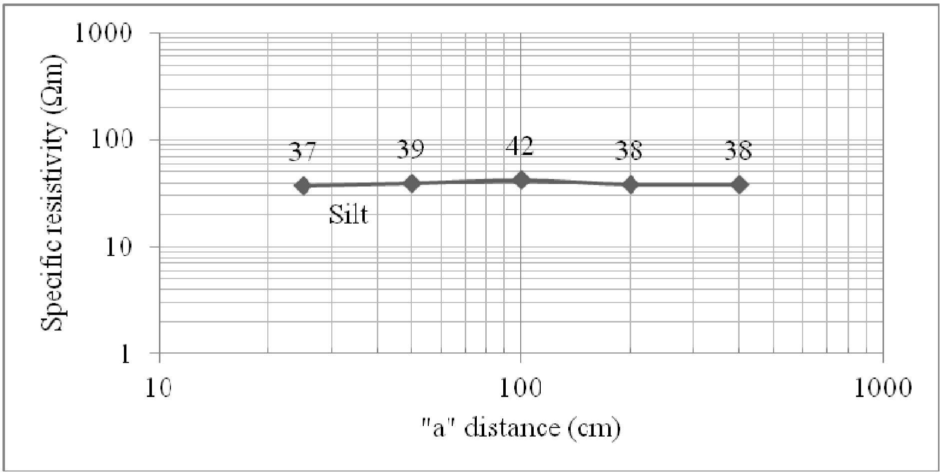

Figure 5 Results of the geophysical sounding at the 5th drilling

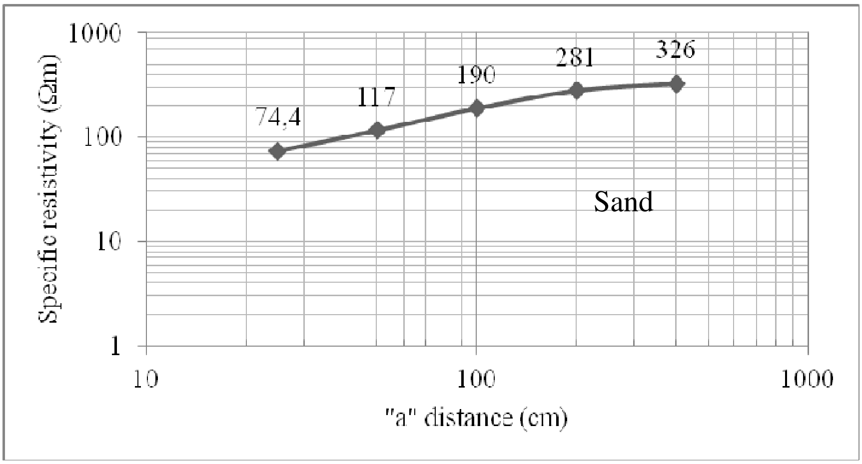

Figure 6. Results of the geophysical sounding at the 6th drilling

Comparing the soil types from drillholes to the resistivity values measured in the same location, we concluded, that the clay sediments give the lowest specific resistivity values, less than 30 Ωm. The specific resistivity values of silt were between 30 and 100 Ωm and the values of sand are more than 100-110 Ωm. These typical values can be explained with the different water holding capacity of different soil types, related to the porosity of the rock and the salinity of the saturating fluid.

Calibrating and correlating the drilling results and the characteristic values of rock resistivity, we attempted to draw the sedimentary soil profile of the three pilot-study area crossing the old riverbeds.

On Fig. 7 the soil profile of the "A" study area was presented. On the northwest side of the profile the resistivity values indicated the presence of silt. Moving to the middle of the old riverbed the specific resistivity values were continuously decreasing.

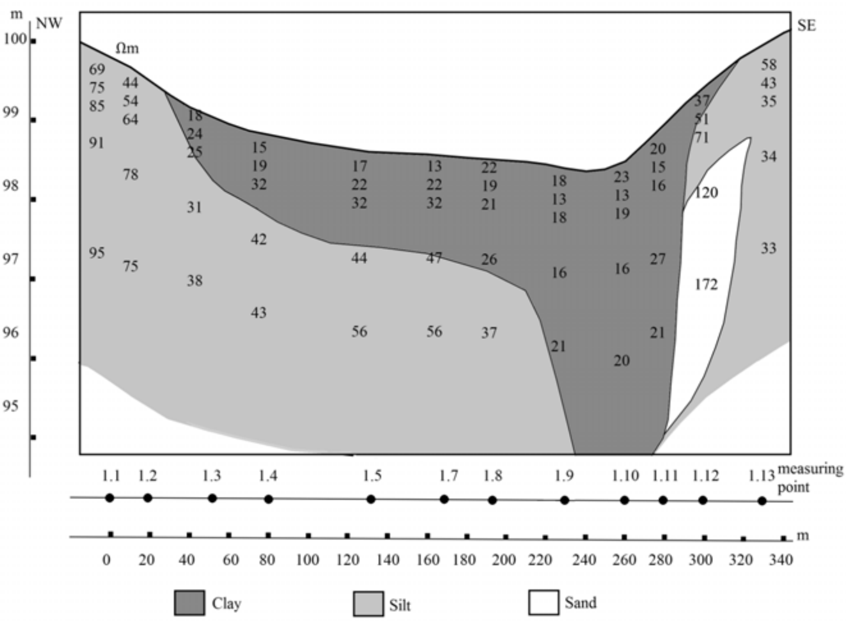

Figure 7. Soil profile of the "A" study area

From the measuring point 1.3 clay in the upper layer is observed. By measuring point 1.9, 1.10 and 1.11 the soundings gave low specific resistivity values, approaching the category of clay. This means that there was a thick clay layer. Moving to the direction of the riverbed edge the resistivity values start the increase, and the clayey soil is changing to silt. At the measuring point 1.12 below the clay and the silt layer sand was detected, which can be presented there as a result of slipping from the steep edge.

In the case of the soil profile of the "B" study area on the western edge, high resistivity values were measured. For example at measuring point 2.5, more than 100 Ωm resistivity values were detected, which indicate the beginning of a sand layer. Moving from the edge of the riverbed to the direction of the centre, the resistivity values decreased. At the measuring point 2.4 and 2.3 silt was the typical sediment, but at 2.2 and 2.1 below a thin silty deposit clay was detected (Fig. 8).

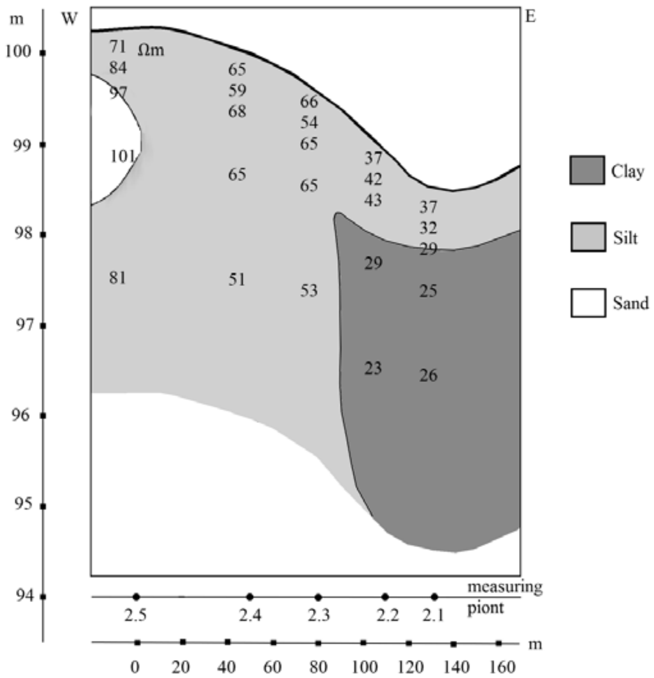

Figure 8. Soil profile of the "B" study area

On Fig. 9 the soil profile of the “C” study area was presented. On the northern edge of the riverbed at first silt sediment was measured but below sand layer can be found with high, 131-200 Ωm specific resistivity. Moving to the centre of the riverbed, the silt appears again. From the measuring point 3.3 a thin clay layer is detected, which seemed to move to the centre of the riverbed. From the measuring point 3.4 to 3.8 only clay was detected with the geophysical sounding. From 3.8 the clay layer was covered by a thin silt deposit. Moving to the southern edge the specific resistivity values increased and the clay was turning to silt, later to sand.

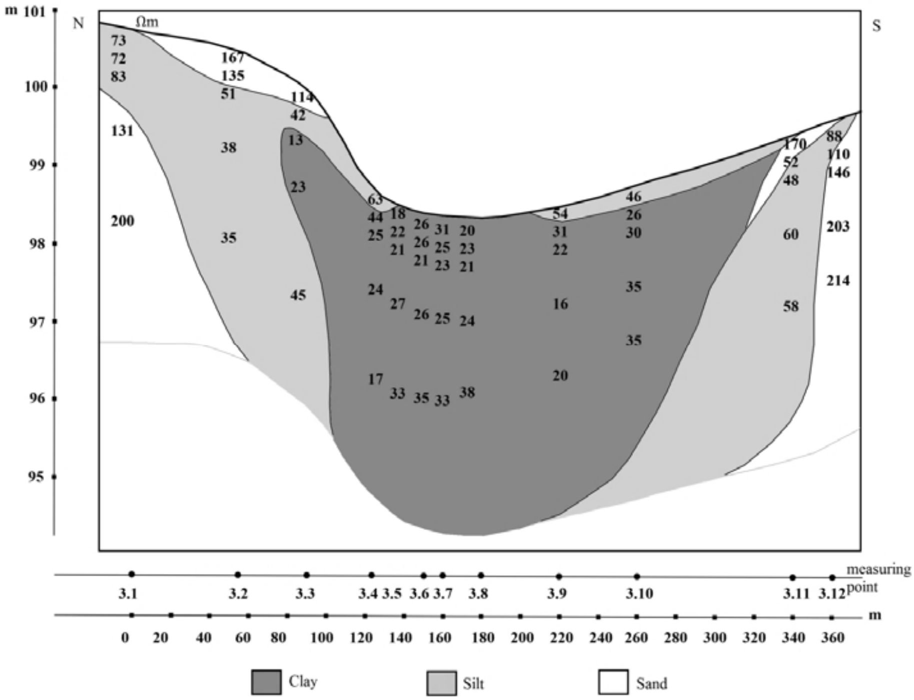

Figure 9. Soil profile of the "C" study area

Conclusion

Comparing the soil types to the specific resistivity values measured in the same location, different soil types in the surveyed area could be characterised by the following resistivity values: clay: < 30 Ωm, silt: 30-100 Ωm, sand: > 100 Ωm.

On the three soil profiles, the central area of the old riverbeds appeared as a few meters thick clay layer with low resistivity values. Moving from the middle to the edges of the river beds the resistivity values increased and the clay was replaced by silt and later by sand.

It is important to know that if artificial streams were led on the old riverbeds, the thickness and the permeability of the sediment would be enough to keep the water in place, on the surface. If we accepted the log-log correlation of Müller et al. (2008) concerning resistivity and hydraulic conductivities in the saturated zone, we could conclude, that the measured resistivity data in the pilot-areas indicate the presence of thick and low permeable sediment. In the central areas of the old river bed the hydraulic conductivity of clay deposits could be estimated about 10^{-7} m/s and outside from the bed, the sand deposits about 10^{-4} m/s.

This sedimentary setting and permeability distribution in the old riverbed indicate that surface water infiltrations into the water table would occur much more laterally, in sands, and less vertically in the clay.

Acknowledgement

This research was supported by the European Union and the State of Hungary, co-financed by the European Social Fund in the framework of TÁMOP 4.2.4. A/2-11-1-2012-0001 'National Excellence Program'.

Present article was published in the frame of the project TÁMOP-4.2.2.A-11/1/KONV-2012-0064, "Regional effects of weather extremes resulting

from climate change and potential mitigation measures in the coming decades" too. The project is realized with the support of the European Union, with the co-funding of the European Social Fund.
We are also very grateful to Tamás Lantos, the Mayor of Markóc, for his help.

References

Buzás, I. 1993. Soil and agrochemical testing method book I. INDA 4231 Publisher, Budapest. p: 37-42.

Gardiner, J.L. 1992. Catchment planning: the way forward for river protection in the UK. In Boon, P.J., Calow, P. and Petts, G.E. (Eds.) River Conservation and Management, J. Wiley and Sons Publishers, New York-London.

Habersack, H.; Piegay, H.; Rinaldi, M. 2008. Gravel Bed Rivers 6: From Process Understanding to River Restoration. Elsevier Publisher, Amsterdam, The Netherlands.

Jelenszkyné Fábián, I. 2009. Gender-based social geographical analysis by the example of Ormánság. PhD Thesis Abstract. University of Pécs, Faculty of Sciences, Doctoral School of Earth Sciences. p: 3-12.

Molnár, G. 2012. The water regulation concept of Ormánság. Manuscript (Unpublished) p: 1-29.

Müller, I.; Mádlné Szőnyi, J.; Erőss, A. 2008. Local scale EM geophysical survey to estimate hydrogeological parameters related to environment problems. *Georgikon for Agriculture*. **11:** 39-48.

Pickett, S.T.A.; Cadenasso, M.L.; Gove J.M.; Nilon, C.H.; Pouyat, R.V.; Zipperer, W.C.; Costanza, R. 2001. Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of Metropolitan Areas. Annual Rev. Ecol. Syst. **32**: 127-57

Rémenyi, P.; Tóth J. 2009. The place and possibilities of Ormánság. ID Research Kft, Pécs, p: 302-355.

Tésits, R. 2007. Regional employment characteristics of the most underdeveloped Hungarian microregions. *Modern Geográfia*. **2**: 3.

Závoczky, Sz. 2005. Hydroelectricity or national park? *Natura Somogyiensis.* **7:** 5-9.

http://baranyakonf2013.pte.hu/en/about-us/old-drava-program/ (Old-Drava Program. 2003. Response-able Communities. Pécs)

http://www.epa.gov/esd/cmb/GeophysicsWebsite/pages/reference/methods/Surface_Geophysical_Methods/Electrical_Methods/Resistivity_Methods.htm

http://www.osdrava.hu/download/tajgazdalkodasi.pdf, 13:26. 11.10. 2013

Aquaprofit Műszaki, Tanácsadási és Befektetési Zrt. 2007. The Landscape Management Program of the Old-Drava Program. pp. 1-143.